Title
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Journal
Science (New York, N.Y.), 355(6324)

ISSN
0036-8075

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Publication Date
2017-02-01

DOI
10.1126/science.aam5432

Peer reviewed

This multiuse silvopastoral landscape in Colombia is an example of forest landscape restoration that improves both ecological integrity and human well-being.

CONSERVATION

Restoring tropical forests from the bottom up

How can ambitious forest restoration targets be implemented on the ground?

By **Karen D. Holl**

Recent initiatives at regional, national, and global scales have called for unprecedented levels of forest restoration to counteract decades of rapid deforestation (*1*, *2*). Thus far, 30 countries have committed to restore 91 million hectares (ha) of deforested landscapes, an area the size of Venezuela, by 2020; at the 2014 United Nations Climate Summit, a global target of 350 million ha was set for 2030 (*1*). These bold targets are motivated by diverse goals, including conserving biodiversity, sequestering carbon, improving the water supply, and sustaining human livelihoods (*2*, *3*). How can these challenging targets be met, given competing land uses and limited funds for restoration?

There is often a striking disconnect between the groups that set restoration targets and those that implement projects and guide restoration science (*3*, *4*). Commitments to restore millions of hectares of forest are made by international groups and national governments, but successfully achieving these targets requires working with individual landowners and local communities. In a recent review, Murcia *et al.* found that only 2 of 90 recent forest restoration projects initiated by government agencies in Colombia involved local communities in the design (*3*). Governments that adopt this top-down approach are unlikely to gain the community support needed to successfully maintain restoration projects over the long term.

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To be successful, restoration efforts also require approaches that are practical at large scales. Yet, the vast majority of scientific studies are conducted in plots of a few to hundreds of m^2 at one or a few sites (*5*). This spatial mismatch is problematic because the methods tested (such as intensive weed removal or moving topsoil from a reference forest as a source of seeds) often are not feasible at large scales. Moreover, results of restoration studies depend on past land-use history, soil type, and other local conditions (*6*). Results from single-site studies can therefore not be generalized to guide restoration projects at scales of a few to hundreds of hectares.

Successfully restoring the amount of forest needed to meet national and international targets requires a frameshift in both restoration planning and science. It requires bottom-up engagement of landowners, nongovernmental organizations, local government leaders, scientists, private restoration businesses, and indigenous and community groups to set restoration goals tailored to regional ecological and socioeconomic conditions and to develop, evaluate, and manage restoration practices that are cost-effective and practical at a large scale (*4*, *7*).

Ecological restoration has historically focused on assisting the recovery of degraded ecosystems toward a narrow set of ecological end points—most often a semblance of predisturbance ecosystem functions and species composition. In contrast, recent "forest landscape restoration" initiatives have aimed to simultaneously improve both ecological integrity and human well-being by balancing multiple restoration goals across the landscape (*2*, *7*). Collaborative planning efforts can identify those locations where restoring large forest areas is most ecologically, socially, and economically feasible and those where

PHOTO: CIPAV

integrating restoration with other land uses may be more advantageous (*4*, *8*, *9*).

For example, forest restoration projects at the scale of tens to hundreds of hectares are more likely to succeed in areas that are less productive for agriculture, protect water supplies used by downstream communities, and have been set aside for conservation purposes (*7*, *9*, *10*). In contrast, efforts to restore forests in highly productive agricultural lands often meet with landowner resistance or displace agricultural activities, causing further forest clearing in other areas (*9*). In such cases, it is more feasible to integrate forest restoration within a mosaic of land uses that increase tree cover in the agricultural landscape and balance multiple goals.

The Atlantic Forest Restoration Pact in Brazil serves as a successful example of bottom-up, multistakeholder engagement in forest restoration planning, implementation, and evaluation (*9*, *11*, *12*). Much of the Atlantic Forest of Brazil was cleared over the past 200 years, with only ~14% of the original forest remaining. For more than 20 years, individual stakeholders worked to restore forest, but these disaggregated efforts led to inefficiencies and unsuccessful outcomes. Hence, in 2009, individual groups came together to form the Pact, which aims to restore 15 million ha of forest on private lands to double forest cover in the next 30 years. The initiative now includes more than 270 nongovernmental organizations, governmental institutions, private companies, and research institutions. These groups have worked synergistically to prioritize areas to meet different restoration goals, evaluate innovative restoration approaches, and develop funding mechanisms to make restoration financially viable (*11*, *12*).

"Successfully restoring the amount of forest needed... requires a frameshift in both restoration planning and science."

Pact stakeholders have developed practical methods for restoring landscapes that are less productive for agriculture. In such areas, the most cost-effective restoration strategy is often to cease anthropogenic land uses and allow forests to regenerate naturally, but rates of natural recovery vary greatly (*10*, *13*). A subset of Pact members, including scientific institutions, have developed landscape models that incorporate field and remotely sensed data to predict where forest is likely to regenerate quickly; this is for example the case within ~200 m of existing forest, as well as on steep slopes with less intensive agricultural use (*14*). In areas that are slower to recover, scientists are testing innovative tree-planting methods, such as planting clusters of native trees over 20 to 25% of the landscape to attract seed-dispersing animals and enhance the rate of forest recovery. This restoration strategy requires fewer resources than plantation-style tree planting and has been shown to be equally effective in enhancing forest recovery in Costa Rica (*6*).

Pact members have also collaborated to test models for increasing tree cover in highly productive agricultural lands, where economic or legal incentives are critical to encourage landowner participation (*12*). In these landscapes, restoration has focused on planting more than 80 species of native tree species along waterways to improve water quality and habitat connectivity, as required by Brazilian forest law. Pact members have lobbied to redirect agricultural subsidies from industrial-scale agriculture to programs that pay farmers for using more environmentally friendly practices and for conserving or restoring ecologically sensitive areas (*9*). These payments for ecosystem services, such as erosion control and carbon sequestration, when combined with income from nontimber forest products and selective logging, can make restoration economically viable (*12*).

Moreover, Brazilian scientists and wood pulp producers are collaborating to test an innovative restoration model, in which fast-growing, economically valuable eucalyptus trees are interplanted with native species, and then the eucalyptus are logged for wood pulp after 6 to 7 years to offset initial planting costs (*9*). Early results suggest that the fast-growing eucalyptus forms a canopy that facilitates the establishment of a diverse suite of native tree seedlings in the understory; the native trees grow quickly after the eucalyptus trees are harvested. Other non-native, economically valuable species, such as pine, can facilitate native tree establishment in some tropical systems (*15*), suggesting this approach could be used more widely for forest landscape restoration.

Another promising example of forest landscape restoration is the integration of trees and nitrogen-fixing shrubs with livestock production. Such silvopastoral systems are expanding in Mexico and Colombia. They increase cattle productivity per hectare, so that grazing can be ceased on steep slopes and along streams to allow for riparian forest restoration and thereby improve water quality and habitat connectivity (*4*, *16*). In Colombia, international and nongovernmental organizations and scientists collaborated with 110 farmers on a pilot project from 2002 to 2007. They provided farmers with short-term payments and technical training to facilitate the transition to silvopastoral methods (see the photo). Results across several farms showed that cattle productivity improved by 44%, the number of bird species increased by 32%, and soil erosion declined by 45%. The Colombian government has now joined the partnership to scale up these methodologies to work with 3500 cattle ranchers, who manage more than 175,000 ha of land across five regions in Colombia (*16*).

These examples of multistakeholder efforts point the way in how to move from aspirational targets to implementing forest landscape restoration. However, longer-term data are needed to evaluate success and adaptively manage these efforts. Forest recovery is a process that takes several decades or more, and most large-scale forest restoration projects are still in their first or second decade. Long-term monitoring and scientific studies are critical to determine whether ecosystems will continue on a desired trajectory, particularly in light of accelerating climatic changes.

Evaluation of the cost and benefits to different stakeholders is equally important, as is the use of both ecological and social data to make management adjustments (*4*). For example, Atlantic Forest Restoration Pact members have collaborated to develop and test a monitoring protocol that includes ecological, social, and management indicators (*12*). In the state of São Paulo, land managers must monitor their projects after 3, 5, 10, 15, and 20 years and share results on the Pact website to evaluate progress toward agreed objectives and learn from others' experiences. These processes of bottom-up, long-term multistakeholder collaborations must become the norm to enhance the success and longevity of large-scale forest restoration efforts. ■

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ACKNOWLEDGMENTS

I appreciate helpful input from P. Brancalion, A. Calle, E. Howard, A. Kulikowski, J. Lesage, J. L. Reid, B. Stanford, and S. Wu.

10.1126/science.aam5432

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Karen D. Holl (February 2, 2017)
Science **355** (6324), 455-456. [doi: 10.1126/science.aam5432]

Editor's Summary